CHAPTER 4

RADIOLOGICAL DOSE ASSESSMENT

Introduction

Each year the potential radiological dose to the public that is attributable to operations and effluents from the West Valley Demonstration Project (WVDP) is assessed to verify that no individual could possibly have received a dose exceeding the limits established by the regulatory agencies. The results of these conservative dose calculations demonstrate that the potential maximum dose to an off-site resident was well below permissible standards and was consistent with the as-low-as-reasonably achievable (ALARA) philosophy of radiation protection.

This chapter describes the methods used to estimate the dose to the general public resulting from exposure to radiation and radionuclides released by the Project to the surrounding environment during 1998. Estimated doses are compared directly to current radiation standards established by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA) for protection of the public. The values are also compared to the annual dose the average resident of the U.S. receives from natural background radiation and to doses reported in previous years for the Project.

Radioactivity. Atoms that emit radiation are called radionuclides. Radionuclides are unstable isotopes that have the same number of protons as any other isotope of the element but different numbers of neutrons, resulting in different atomic masses. For example, the element hydrogen has two stable isotopes, H-1 and H-2 (deuterium), and one radioactive isotope, H-3 (tritium). The numbers following the element's symbol identify the atomic mass, which is the number of protons plus neutrons in the nucleus. Thus, H-1 has one proton and no neutrons, H-2 has one proton and one neutron, and H-3 has one proton and two neutrons.

When radioactive atoms decay by emitting radiation, the daughter products that result may be either radioactive or stable. Generally, radionuclides with high atomic numbers, such as uranium-238 and plutonium-239, have many generations of radioactive progeny. For example, the radioactive decay of plutonium-239 creates uranium-235, thorium-231, protactinium-231, and so on through eleven progeny until only the stable isotope lead-207 remains.

Radionuclides with lower atomic numbers often have no more than one daughter. For example, strontium-90 has one radioactive daughter, yttrium-90, which finally decays into stable zirconium; cobalt-60 decays directly to stable nickel with no intermediate nuclide.

The time required for half of the radioactivity of a radionuclide to decay is referred to as the radionuclide's half-life. Each radionuclide has a unique half-life; both strontium-90 and cesium-137 have half-lives of approximately 30 years while plutonium-239 has a half-life of 24,400 years. Knowledge of radionuclide half-lives is often used to estimate past and future inventories of radioactive material. For example, a 1.0-millicurie source of cesium-137 in 1998 would have measured 2.0 millicuries in 1968 and will be 0.5 millicuries in 2028.

Radiation emitted by radionuclides may consist of electromagnetic rays such as x-rays and gamma rays or charged particles such as alpha and beta particles. A radionuclide may emit one or more of these radiations at characteristic energies that can be used to identify them.

Radiation Dose. The energy released from a radionuclide is eventually deposited in matter encountered along the path of the radiation. The radiation energy absorbed by a unit mass of material is referred to as the absorbed dose. The absorbing material can be either inanimate matter or living tissue.

Alpha particles leave a dense track of ionization as they travel through tissue and thus deliver the most dose per unit-path length. However, alpha particles are not penetrating and must be taken into the body by inhalation or ingestion to cause harm. Beta and gamma radiation can penetrate the protective dead skin layer of the body from the outside, exposing the internal organs.

Because beta and gamma radiations deposit much less energy in tissue per unit-path length relative to alpha radiation, they produce fewer biological effects for the same absorbed dose. To allow for the different biological effects of different kinds of radiation, the absorbed dose is multiplied by a quality factor to yield a unit called the dose equivalent. A radiation dose expressed as a dose equivalent, rather than as an absorbed dose, permits the risks from different types of radiation exposure to be compared to each other (e.g., exposure to alpha radiation compared to exposure to gamma radiation). For this reason, regulatory agencies limit the dose to individuals in terms of total dose equivalent.

Units of Measurement. The unit for dose equivalent in common use in the U.S. is the rem, which stands for roentgen-equivalent-man. The international unit of dose equivalent is the sievert (Sv), which is equal to 100 rem. The millirem (mrem) and millisievert (mSv), used more frequently to report the low dose equivalents encountered in environmental exposures, are equal to one-thousandth of a rem or sievert.

The effective dose equivalent (EDE), also expressed in units of rem or sievert, provides a means of combining unequal organ and tissue doses into a single "effective" whole body dose that represents a comparable probability of inducing a fatal cancer. The probability that a given dose will result in the induction of a fatal cancer is referred to as the risk associated with that dose. The EDE is calculated by multiplying the organ dose equivalent by the organ-weighting factors developed by the International Commission on Radiological Protection (ICRP) in Publications 26 (1977) and 30 (1979). The weighting factor is a ratio of the risk from a specific organ or tissue dose to the total risk resulting from an equal whole body dose. All organ-weighted dose equivalents are then summed to obtain the EDE.

The dose from internally deposited radionuclides calculated for a fifty-year period following intake is called the fifty-year committed effective dose equivalent (CEDE). The CEDE sums the dose to an individual over fifty years to account for the biological retention of radionuclides in the body. The total EDE for one year of exposure to radioactivity is calculated by adding the CEDE to the dose equivalent from external, penetrating radiation received during the year. Unless otherwise specified, all doses discussed here are EDE values, which include the CEDE for internal emitters.

A collective population dose is expressed in units of person-rem or person-sievert because the individual doses are summed over the entire potentially exposed population. The average individual dose can therefore be obtained by dividing the collective dose by the number in the population.

Sources of Radiation. Members of the public are routinely exposed to different sources of ionizing radiation from both natural and manmade sources. Figure 4-1 (*below*) shows the relative contribution to the annual dose in millirem from these sources in comparison to the estimated 1998 maximum individual dose from the WVDP. The National Council on Radiation Protection and Measurements (NCRP) Report 93 (1987) estimates that the average annual effective dose equivalent received by an individual living in the U.S. is about 360 mrem (3.6 mSv) from both natural and manmade sources of radiation.

While most of the radiation dose received by the general public is natural background radiation, manmade sources of radiation also contribute to the average dose. Such sources include diagnostic and therapeutic x-rays, nuclear medicine, fallout from atmospheric nuclear weapons tests, effluents from nuclear fuel cycle facilities, and consumer products such as smoke detectors and cigarettes.

As can be seen in Figure 4-1 (*below*), natural sources of radiation contribute 295 mrem (2.95 mSv) and manmade sources contribute 65 mrem (0.65 mSv) of the total annual U.S. average dose of 360 mrem (3.60 mSv). The WVDP contributed a very small amount (0.065 mrem [0.00065 mSv]) to the total annual manmade radiation dose to the maximally exposed individual residing near the WVDP. This is much less than the average dose received from using consumer products and is insignificant compared to the federal standard of 100 mrem from manmade sources or the 295 mrem received annually from natural sources.

Health Effects of Low-level Radiation. Radionuclides entering the body through air, water, or food are distributed in different organs of the body. For example, isotopes of iodine concentrate in the thyroid. Strontium, plutonium, and americium isotopes concentrate in the skeleton. When inhaled, uranium and plutonium isotopes remain in the lungs for a long period of time. Some radionuclides such as tritium, carbon-14,

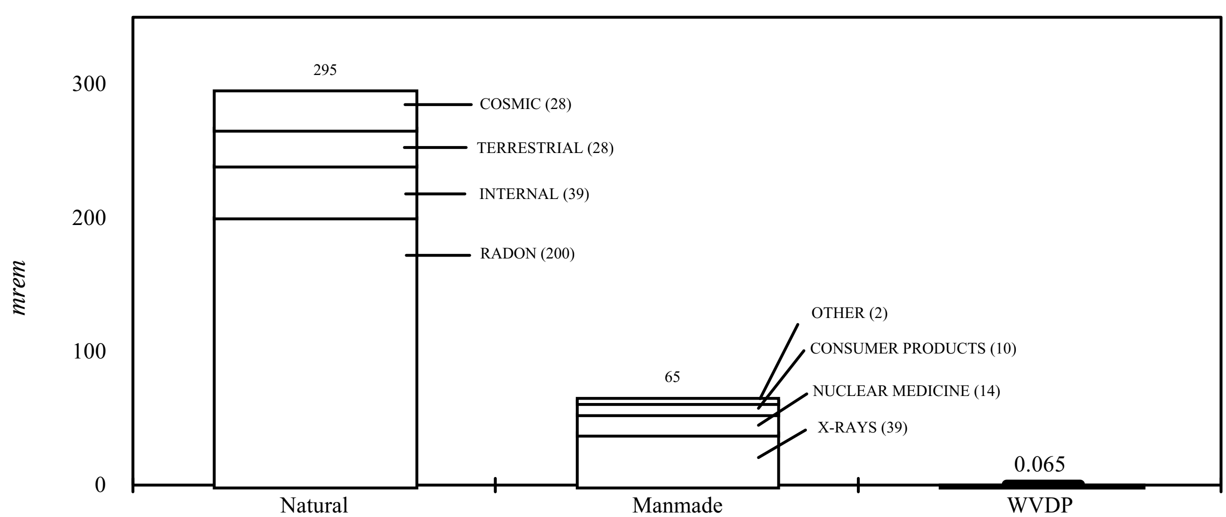

Figure 4-1. Comparison of Annual Background Radiation Dose to the Dose from 1998 WVDP Effluents

or cesium-137 are distributed uniformly throughout the body. Therefore, depending on the radionuclide, some organs may receive quite different doses. Moreover, at the same dose levels, certain organs (such as the breast) are more prone to developing a fatal cancer than other organs (such as the thyroid).

Because of the uncertainty and difficulty in measuring the incidence of increased cancer resulting from exposure to ionizing radiation, to be conservative, a linear model is used to predict health risk from low levels of radiation. This model assumes that there is a risk associated with all dose levels even though the body may effectively repair damage incurred from low levels of alpha, beta, and gamma radiations.

Exposure Pathways

The radionuclides present at the WVDP site are residues from the reprocessing of commercial nuclear fuel during the 1960s and early 1970s. A very small fraction of these radionuclides is released off-site during the year through ventilation systems and liquid discharges and makes a negligible contribution to the radiation dose to the surrounding population through a variety of exposure pathways.

An exposure pathway consists of a source of contamination or radiation that is transported by environmental media to a receptor where exposure to contaminants may occur. For example, a member of the public could be exposed to low levels of radioactive particulates carried by prevailing winds.

The potential pathways of exposure from Project emissions are inhalation of gases and particulates, ingestion of local food products, ingestion of fish, beef, and deer tissues, and exposure to external penetrating radiations emanating from contaminated materials. The drinking water pathway was excluded from calculations of potential maximum dose to individuals because surveys revealed that local residents do not use water from Cattaraugus Creek as drinking water. Table 4-1 (*facing page*) summarizes the potential exposure pathways for the local off-site population.

Land Use Survey

Periodic surveys of local residents provide information about local family sizes, sources of food, and gardening practices. Information from the most recent survey, conducted in 1996, was used to confirm the locations of the nearest residences and other population parameters. These parameters are required for computer models that are used for the annual dose assessments. (See the discussion of Dose Assessment Methodology [p.4-6] for more information on the computer model used.)

1998 Deer Management Program

In 1997 NYSDEC biologists assisted the Project in collecting four on-site deer in order to obtain tissue samples for analysis. The data were used to determine whether radioactivity levels in on-site deer were sufficiently low to allow the animals to be moved from the Project premises to the WNYNSC. As described in the Deer Management Program Plan (West Valley Nuclear Services Co., Inc. October 27, 1997), the deer drives were necessary because on-site sources of food could not support the large number of deer.

The results of the analyses indicated that the average concentration of cesium-137 in venison samples collected from the north plateau was approximately thirty times higher than average concentrations in venison collected from control locations more than sixteen kilometers from the Project. As the element cesium has a biological half-life in deer of less than thirty days, once the deer were removed from the north plateau during the deer drives, which took place January 8 and 9, 1998, the cesium-137 in their bodies be-

Table 4-1
Potential Local Off-Site Exposure Pathways Under Existing WVDP Conditions

Exposure Pathway and Transporting Medium	**Reason for Inclusion/Exclusion**
Inhalation: gases and particulates in air (included)	Off-site transport of contaminants from WVDP stacks or resuspended particulates from soils
Ingestion: cultivated crops (included)	Local agricultural products irrigated with contaminated ground- or surface water; foliar deposition and uptake of airborne contaminants
Ingestion: surface and groundwater (excluded)	No documented use of local surface water or downgradient groundwater wells as drinking water by local residents
Ingestion: fish, beef, venison, and milk (included)	Fish exposed to contaminants in water or sediments may be consumed; beef, venison, and milk consumption following deposition of transported airborne and surface water contaminants
External exposure: radiation emanating from particulates and gases from air or surface water (included)	Transport of air particulates and gases to off-site receptors; transport of contaminants in surface water and direct exposure during stream use and swimming

gan to be naturally eliminated at a rate of at least half of the remaining amount each month. The calculated hypothetical effective dose equivalent that could have been received by an individual eating 100 pounds of venison taken from deer immediately after the deer drive was 0.76 mrem. However, the deer were not legally hunted again until mid-October 1998, at which time the estimated effective dose equivalent from exposure to the remaining cesium-137 in venison was no greater than that from consuming venison collected from control locations.

In March 1998 all but four of the deer remaining on the site after the January deer drives were baited off the WVDP premises using a commercial food source. These four deer were harvested and sampled, and the venison was analyzed for cesium-137. The average cesium-137 concentration was lower than that of venison from the deer collected in October 1997 (possibly because of the addition of commercial feed to the diet) and was statistically the same as that in background venison samples collected more than 20 kilometers (12 mi) from the site.

Radioactive Vitrification Operations

The start of radioactive vitrification operations in June/July 1996 resulted in an increase of radioactive emissions from the main plant stack. Specifically, the release rate of iodine-129 increased from a 1993-1995 average of 25 microcuries (μCi) per year to 1,200 μCi in 1996 and 7,430 μCi in 1997 as a result of the processing of the high-level waste. In 1998 the yearly release of iodine-129 fell to 4,970 μCi/yr due to the completion of Phase I of vitrification. (See Chapter 2, p. 2-24, Special Monitoring, for further discussion of iodine-129 emissions from the main plant stack.)

Dose Assessment Methodology

The potential radiation dose to the general public from activities at the WVDP is evaluated by using a two-part methodology and following the requirements in DOE Order 5400.5. The first part uses the measurements of radionuclide concentrations in liquid and air discharges from the Project. (See Appendix C and Appendix D.) These data, together with meteorological and demographic information, are input to computer models that calculate the potential or estimated doses, rather than actual radiation doses, from all credible pathways to individuals and the population.

Because of the difficulty of distinguishing the small amount of radioactivity emitted from the site from that which occurs naturally in the environment, computer codes are used to model the environmental dispersion of radionuclides emitted from on-site monitored ventilation stacks and liquid discharge points. The EDE to the maximally exposed off-site individual and the collective EDE to the population within a 50-mile radius is calculated using models that have been approved by the DOE and the EPA to demonstrate compliance with radiation standards.

Radiological dose is evaluated for all major exposure pathways, including external irradiation, inhalation, and ingestion of local food products. The dose contributions from each radionuclide and pathway combination are then summed to obtain the total dose estimates reported in Table 4-2 (*facing page*).

The second phase of the dose assessments is based on measurement of radioactivity in foodstuffs sampled in the vicinity of the WVDP and the comparison of these values with measurements of samples collected from locations well beyond the potential influence of site effluents. These measurements of environmental media show that the concentrations of radioactivity are small and usually are near the analytical detection limits, thereby providing additional assurance that operations at the WVDP are not adversely affecting the public.

If any of the near-site food samples contain radionuclide concentrations that are statistically higher than the concentrations in control samples, separate dose calculations are performed. However, these calculated doses are not added to the estimates that are based on predictive computer modeling (Table 4-2 [*facing page*]) because the models already include contributions from all environmental pathways.

Comparison of Near-site and Background Environmental Media Concentrations. Near-site and control (background) samples of fish, milk, beef, venison, and local produce were collected and analyzed for various radionuclides, including tritium, cobalt-60, strontium-90, iodine-129, and cesium-137. The measured radionuclide concentrations reported in Appendix F, Tables F-1 through F-4 (pp.F-3 through F-8) are the basis for comparing near-site and background concentrations.

If differences are found between near-site and background sample concentrations, the amount by which the near-site sample concentration ex-

Table 4-2

Summary of Annual Effective Dose Equivalents to an Individual and Population from WVDP Releases in 1998

Exposure Pathways	**Annual Effective Dose Equivalent**	
	Maximally Exposed Off-Site Individual [1] mrem (mSv)	***Collective Effective Dose Equivalent [2] person-rem (person-Sv)***
Airborne Releases [3]	3.4E-02 (3.4E-04)	2.6E-01 (2.6E-03)
% EPA standard (10 mrem)	0.34%	*NA*
Waterborne Releases [4]		
Effluents only	8.1E-03 (8.1E-05)	7.7E-03 (7.7E-05)
Effluents plus north plateau drainage	3.1E-02 (3.1E-04)	6.7E-02 (6.7E-04)
Total from all Pathways	6.5E-02 (6.5E-04)	3.3E-01 (3.3E-03)
% DOE standard (100 mrem) — air and water combined	0.065%	
% natural background (295 mrem; 380,000 person-rem) — air and water combined	0.022%	0.00009%

Exponents are expressed as "E" in this report: a value of 1.2×10^{-4} in scientific notation is reported as 1.2E-04 in the text and tables.

NA — Not applicable. Numerical regulatory standards are not set for the collective EDE to the population.

[1] *Maximum exposure to air discharges occurs at a residence 1.8 kilometers northwest of the main plant.*

[2] *Population of 1.3 million within 80 kilometers of the site.*

[3] *From atmospheric release point sources. Calculated using CAP88-PC for individual and population.*

[4] *Calculated using methodology described in Radiological Parameters for Assessment of WVDP Activities (Faillace and Prowse 1990).*

ceeded background is used to calculate a potential maximum individual dose for comparison with dose limits and the dose from background alone. If no differences in concentrations are found, then no further assessment is conducted.

The maximum potential dose to nearby residents from the consumption of foods with radionuclide concentrations above background is calculated by multiplying the excess concentrations by the maximum adult annual consumption rate for each type of food and the unit dose conversion factor for ingestion of the measured radionuclide. The consumption rates are based on site-specific data and recommendations in NRC Regulatory Guide 1.109 for terrestrial food chain dose assessments (U.S. Nuclear Regulatory Commission October 1977). The internal dose conversion factors were obtained from Internal Dose Conversion Factors for Calculation of Dose to the Public (U.S. Department of Energy July 1988).

Fish. Samples of fish were collected from Cattaraugus Creek from May 1998 through November 1998. Twenty fish were collected both at background locations upstream of the site and at locations downstream of the site above the Springville dam. Ten fish were collected at points downstream of the site below the dam.

Edible portions of all fish samples were analyzed for strontium-90 and cesium-137, and the values were compared to background values. (See Table F-4 [pp.F-6 through F-8].) Average values for cesium-137 were either below detection limits or not statistically different from control concentrations. Strontium-90 concentrations in some individual fish collected downstream of the site, above the Springville dam, were higher than control sample concentrations. The calculated maximum dose to an individual from consuming 21 kilograms (46 lbs) of near-site fish was 0.008 mrem (0.00008 mSv). This annual dose is roughly equivalent to the dose received every fifteen minutes from natural background radiation.

Milk. Milk samples were collected from various nearby dairy farms throughout 1998. Control samples were collected from farms 25 to 30 kilometers (15-20 mi) to the south and north of the WVDP. Milk samples were analyzed for tritium, strontium-90, iodine-129, cesium-137, and potassium-40. (See Table F-1 [p.F-3].) Ten near-site milk samples were collected and compared with eight background samples. Average values for tritium, iodine-129, and cesium-137 were either below detection limits or not statistically different from control concentrations.

The average strontium-90 concentration in milk at a near-site sample location was above the average background concentration. The hypothetical maximum dose to an individual from consuming 310 liters (82 gal) of near-site milk was 0.22 mrem (0.0022 mSv). This annual dose is roughly equivalent to the dose received every seven hours from natural background radiation.

Beef. Near-site and control samples of locally raised beef were collected in 1998. These samples were analyzed for tritium, strontium-90, and cesium-137. Two samples of beef muscle tissue were collected from background locations and two from near-site locations.

Individual concentrations of tritium and cesium-137 in near-site samples were either below detection limits or not statistically different from concentrations at control locations. (See Table F-2 [p.F-4].) The strontium-90 concentration in one near-site beef sample was higher than the control concentration. The hypothetical maximum dose to an individual from consuming 110 kilograms (243 lbs) of beef from this location was 0.022 mrem (0.00022 mSv). This annual dose is roughly equivalent to the dose received every forty minutes from natural background radiation.

Venison. Meat samples from three near-site and three control deer were collected in 1998. (See Table F-2 [p.F-4].) These samples were measured for tritium, strontium-90, cesium-137, and other gamma-emitting radionuclides. Individual concentrations of tritium and strontium-90 in near-site venison samples were either below detection limits or not statistically different than concentrations at control locations. One near-site venison sample contained cesium-137 concentrations higher than the control sample concentrations. The calculated maximum dose to an individual from consuming 45 kilograms (100 lbs) of near-site venison was 0.20 mrem (0.0020 mSv). This annual dose is roughly equivalent to the dose received every six hours from natural background radiation.

Produce (corn, beans, and apples). Near-site and background samples of corn, beans, and apples were collected during 1998 and analyzed for tritium, cobalt-60, strontium-90, potassium-40, and cesium-137. (See Appendix F, Table F-3 [p.F-5].)

Individual concentrations of tritium, cobalt-60, and cesium-137 in near-site produce samples were either below detection limits or not statistically different from concentrations at control locations. Strontium-90 concentrations in annual near-site corn samples were above the control concentrations. The hypothetical maximum dose to an individual from consuming 52 kilograms (115 lbs) of near-site corn was 0.013 mrem (0.00013 mSv). This annual dose is roughly equivalent to the dose received every twenty-five minutes from natural background radiation.

See Appendix B (pp.B-37 through B-40) for the locations from which background biological samples are collected.

Predicted Dose from Airborne Emissions

Airborne emissions of radionuclides are regulated by the EPA under the Clean Air Act and its implementing regulations. DOE facilities are subject to 40 CFR 61, Subpart H, National Emissions Standards for Hazardous Air Pollutants (NESHAP). The applicable standard for radionuclides is a maximum of 10 mrem (0.1 mSv) EDE to any member of the public in any year.

Releases of airborne radioactive materials from nominal 10-meter stacks and from the main 60-meter stack are modeled using the EPA-approved CAP88-PC computer code (U.S. Environmental Protection Agency March 1992). This air dispersion code estimates effective dose equivalents for the ingestion, inhalation, air immersion, and ground surface pathways. Site-specific data for radionuclide release rates in curies per year, wind data, and the current local population distribution are used as input parameters. Resulting output from the CAP88-PC code is then used to determine the total EDE to a maximally exposed individual and the collective dose to the population within an 80-kilometer (50-mi) radius of the WVDP.

As reported in Chapter 2, Environmental Monitoring, the main 60-meter stack and several shorter stacks were monitored for radioactive air emissions during 1998. The activity that was released to the atmosphere from these emission points is listed in Tables D-1 through D-11 and D-15. (See Appendix D, pp.D-3 through D-12 and D-16.) Appropriate information from these tables was used as input to the CAP88-PC code.

Wind data collected from the on-site meteorological tower during 1998 were used as input to the CAP88-PC code. Data collected at the 60-meter and 10-meter heights were used in combination with the main plant stack and ground-level effluent release data, respectively.

Maximum Dose to an Off-site Individual. Based on the airborne radioactivity released from the permitted point sources at the site during 1998, it was estimated that a person living in the vicinity of the WVDP could have received a

The Main Plant Ventilation Stack at the WVDP

total EDE of 0.034 mrem (0.00034 mSv). The computer model has established that this maximally exposed off-site individual is located 1.8 kilometers northwest of the site and is assumed to eat only locally produced foods. Approximately 99% of the dose is from iodine-129, emitted from the main stack.

The maximum total EDE of 0.034 mrem (0.00034 mSv) from the permitted stacks and vents is far below levels that could be measured at the exposed individual's residence. This dose is comparable to about one and one-half hours of natural background radiation received by an average member of the U.S. population and is well below the 10 mrem (0.1 mSv) NESHAP limit promulgated by the EPA and required by DOE Order 5400.5.

Collective Population Dose. The CAP88-PC version of AIRDOS-EPA was used to estimate the collective EDE to the population. The population data that were used for the 1998 assessment are from the most recent census projection, which was for 1995. In this five-year projection, 1.3 million people were estimated to reside within 80 kilometers (50 mi) of the WVDP. This population received an estimated 0.26 person-rem (0.0026 person-Sv) total EDE from radioactive airborne effluents released from the permitted WVDP point sources during 1998. The resulting average EDE per individual was 0.0002 mrem (0.000002 mSv).

Predicted Dose from Waterborne Releases

Currently there are no EPA standards establishing limits on the radiation dose to members of the public from liquid effluents except as applied in 40 CFR 141 and 40 CFR 143, Drinking Water Guidelines (U.S. Environmental Protection Agency 1984a; 1984b). The potable-water wells sampled for radionuclides are upgradient of the WVDP and therefore are not a potential source of exposure to radiation from Project activities. Since Cattaraugus Creek is not used as a drinking water supply, a comparison of the predicted concentrations and doses to the EPA drinking water limits established in 40 CFR 141 and 40 CFR 143 is not truly appropriate (although the values in creek samples are well below the EPA drinking water limits).

The estimated radiation dose was compared to the applicable guidelines provided in DOE Order 5400.5. The EDE to the maximally exposed off-site individual and the collective EDE to the population due to routine waterborne releases and natural drainage are calculated using dose conversion factors as reported in Radiological Parameters for Assessment of WVDP Activities (Faillace and Prowse 1990).

Since the effluents eventually reach Cattaraugus Creek, which is not used directly as a source of drinking water, the most important individual exposure pathway is the consumption of fish by local sportsmen. It is assumed that a person may consume annually as much as 21 kilograms (46 lbs) of fish caught in the creek. Exposure to external radiation from shoreline or water contamination also is included in the model for estimating radiation dose. Population dose estimates assumed that radionuclides were further diluted in Lake Erie before reaching municipal drinking water supplies. The computer code LADTAP II (Simpson and McGill 1980) was used to calculate the dose conversion factors for routine waterborne releases and dispersion of these effluents. Input data included site-specific stream flow and dilution, drinking water usage, and stream usage factors. A detailed description of LADTAP II is given in Radiological Parameters for Assessment of WVDP Activities (Faillace and Prowse 1990).

Six planned batch releases of liquid radioactive effluents from lagoon 3 occurred during 1998. The radioactivity that was discharged in these effluents is listed in Appendix C, Table C-1 (p. C-3) and was used with the dose conversion factors to calculate the EDE to the maximally exposed off-site individual and the collective EDE to the population.

In addition to the batch releases from lagoon 3 (WNSP001), effluents from the sewage treatment facility (WNSP007) and the french drain (WNSP008) are routinely released. The activities measured from these release points were included in the EDE calculations. The measured radioactivity concentrations from the sewage treatment facility and french drain are presented in Appendix C, Tables C-5 and C-6 (p.C-7).

In addition to the above discharges there are two natural drainage channels originating on the Project premises with measurable amounts of radioactivity. These are drainages from the northeast swamp (WNSWAMP) and north swamp (WNSW74A). The measured radioactivity from these points is reported in Tables C-7 and C-8 (pp.C-8 and C-9). These release points are included in the EDE calculations for the maximally exposed off-site individual and the collective population.

Maximum Dose to an Off-site Individual. Based on the radioactivity in liquid effluents released from the WVDP (lagoon 3, sewage treatment plant, and french drain) during 1998, an off-site individual could have received a maximum EDE of 0.0081 mrem (0.000081 mSv). Approximately 73% of this dose would be from cesium-137 and 12% from strontium-90. This dose of 0.0081 mrem (0.000081 mSv) is negligible in comparison to the 295 mrem (2.95 mSv) that an average member of the U.S. population receives in one year from natural background radiation.

The maximum off-site individual EDE due to drainage from the north plateau (north swamp and northeast swamp) is 0.022 mrem (0.00022 mSv). (See Appendix C, Tables C-7 and C-8 [pp.C-8 and C-9].) The combined EDE to the maximally exposed individual from liquid effluents and drainage is 0.031 mrem (0.00031 mSv). This annual dose is negligible in comparison to the 295 mrem (2.95 mSv) that an average member of the U.S. population receives in one year from natural background radiation.

Collective Dose to the Population. As a result of radioactivity released in liquid effluents from the WVDP (lagoon 3, sewage treat-

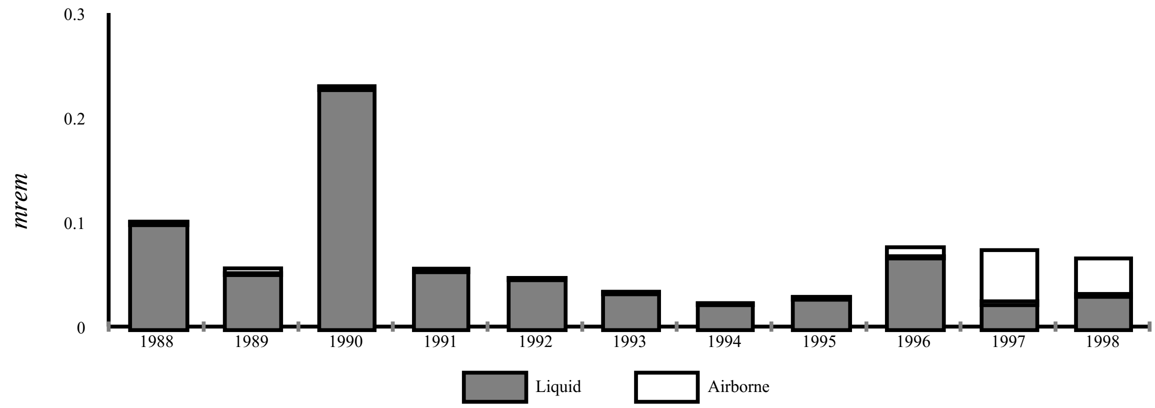

Figure 4-2. Effective Dose Equivalent from Liquid and Airborne Effluents to a Maximally Exposed Individual Residing near the WVDP

ment plant, and french drain) during 1998, the population living within 80 kilometers (50 mi) of the site received a collective EDE of 0.0077 person-rem (0.000077 person-Sv). The collective dose to the population from the north plateau drainage is 0.06 person-rem (0.0006 person-Sv).

This estimate is based on a population of 1.3 million living within the 80-kilometer radius. The resulting average EDE from lagoon 3, the sewage treatment plant, the french drain, and north plateau drainage (north swamp and northeast swamp) per individual is 5.2E-05 mrem (5.2E-07 mSv). This dose of 0.000052 mrem (0.00000052 mSv) is an inconsequential addition to the dose that an average person receives in one year from natural background radiation.

Predicted Dose from All Pathways

The potential dose to the public from both airborne and liquid effluents released from the Project during 1998 is the sum of the individual dose contributions. The calculated maximum EDE from all pathways to a nearby resident was 0.065 mrem (0.00065 mSv). This dose is approximately 0.07% of the 100 mrem (1 mSv) annual limit in DOE Order 5400.5.

The total collective EDE to the population within 80 kilometers (50 mi) of the site was 0.33 person-rem (0.0033 person-Sv), with an average EDE of 0.00025 mrem (0.0000025 mSv) per individual.

Table 4-2 (p. 4-7) summarizes the dose contributions from all pathways and compares the individual doses to the applicable standards.

Figure 4-2 (*above*) shows the calculated annual dose to the hypothetical maximally exposed individual over the last eleven years. The estimated dose for 1998 is slightly lower than the annual dose reported for 1997. The slight decrease in dose fraction from air emissions in 1998 is attributed to the decrease in iodine-129 emissions. The increased dose from the liquid pathway was the result of a 50% increase in strontium-90 released from the north plateau drainage. This increase is a result of the migration of the gross beta plume. (See Special Groundwater Monitoring in Chapter 3, p.3-15.)

Figure 4-3 (*facing page*) shows the collective dose to the population over the last eleven years. The upward trend, primarily from an increase in iodine-129 emissions from the main plant stack after the start of radioactive vitrification operations in June/July 1996, was not continued in 1998. These data confirm the continued inconsequential addition to the natural background radiation dose that the individuals and population around the WVDP receive from Project activities.

Unplanned Releases

There were no off-site unplanned releases (as defined by DOE Order 5400.1) of radioactive materials in air or liquid effluent identified or reported in 1998.

Risk Assessment

Estimates of cancer risk from ionizing radiation have been presented by the International Commission on Radiological Protection (1990), the National Council on Radiation Protection and Measurement (1987), and the National Research Council Committee on Biological Effects of Ionizing Radiation (1990). These reports estimate that the probability of fatal cancer induction to the public, averaged over all ages, ranges from 0.0001 to 0.0005 cancer fatalities/rem. The most recent risk coefficient of 0.0005 (International Commission on Radiological Protection 1991) was used to estimate risk to a maximally exposed off-site individual. The resulting risk to this hypothetical individual from airborne and waterborne releases was a 0.000000033 probability of a cancer fatality (1 chance in 31 million). This risk is well below the range of 0.000001 to 0.00001 per year considered acceptable by the International Commission on Radiological Protection Report 26 (1977) for any individual member of the public.

Summary

Predictive computer modeling of airborne and waterborne releases resulted in estimated hypothetical doses to the maximally exposed individual that were orders of magnitude below all applicable EPA standards and DOE Orders, which place limitations on the release of radioactive materials and dose to individual members of the public. The collective population dose also was assessed and found to be orders of magnitude below natural background radiation doses. Based on the dose assessment, the WVDP was found to be in compliance with all applicable effluent radiological guidelines and standards during 1998.

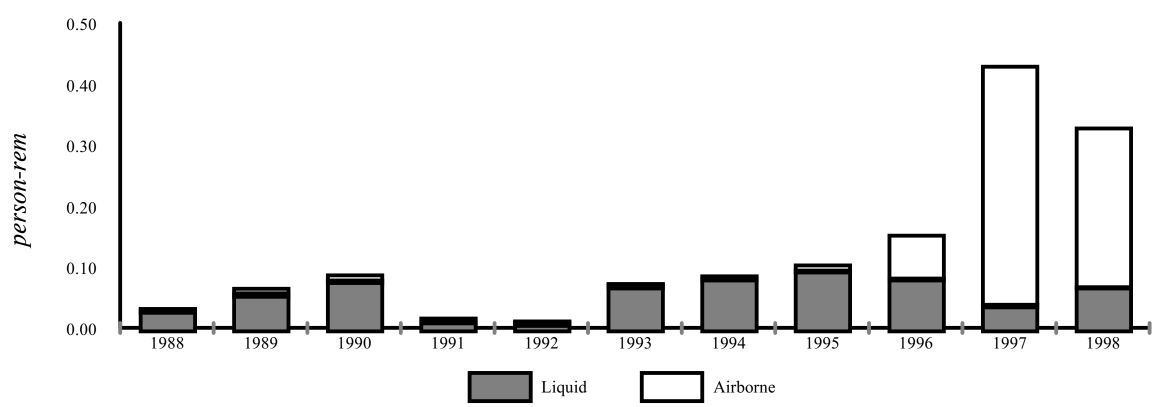

Figure 4-3. Collective Effective Dose Equivalent from Liquid and Airborne Effluents to the Population Residing within 80 Kilometers of the WVDP